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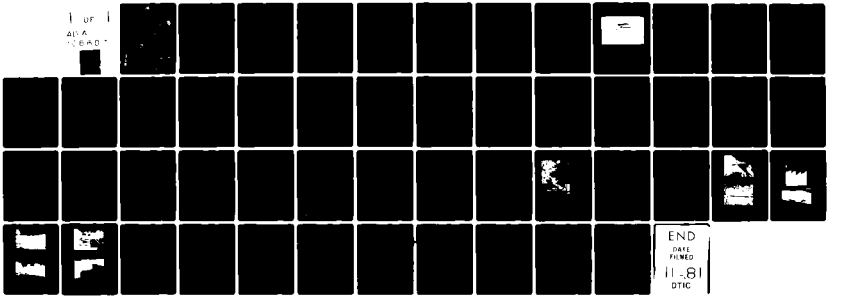

LEVEL II

MISSISSIPPI-KASKASKIA-ST. LOUIS BASIN

AD A106607

RICHWOODS MINE 'B' MILL DAM
WASHINGTON COUNTY, MISSOURI
MO. 31404

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY INSPECTION

United States Army
Corps of Engineers
...Serving the Army
...Serving the Nation

St. Louis District

PREPARED BY: U.S. ARMY ENGINEER DISTRICT, ST. LOUIS

FOR: STATE OF MISSOURI

SEPTEMBER 1980

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Dam Safety, Lake, Dam Inspection, Private Dams

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.

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DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 TUCKER BOULEVARD, NORTH
ST. LOUIS, MISSOURI 63101

REPLY TO ATTENTION OF

SUBJECT: Richwoods Mine 'B' Mill Dam (MO 31404)

This report presents the results of field inspection and evaluation of the Richwoods Mine 'B' Mill Dam (MO 31404). It was prepared under the National Program of Inspection of Non-Federal Dams.

The inspection results indicate problems with the discharge from the impoundment which runs along a portion of the dam toe. (See photos 3 and 4). It appears this discharge channel has eroded the toe of the downstream slope and evidence of small slope failures were noted in this area.

SUBMITTED BY: SIGNED — 24 SEP 1980
Chief, Engineering Division — Date

APPROVED BY: SIGNED — 24 SEP 1980
Colonel, CE, District Engineer — Date

RICHWOODS MINE B MILL DAM

Washington County, Missouri

Missouri Inventory No. 31404

Phase I Inspection Report

National Dam Safety Program

Prepared by

Woodward-Clyde Consultants

Chicago, Illinois

Under Direction of

St Louis District, Corps of Engineers

for

Governor of Missouri

September 1980

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams for Phase I Investigations. Copies of these guidelines may be obtained from the Office of the Chief of Engineers, Washington, D. C., 20314. The purpose of a Phase I investigation is not to provide a complete evaluation of the safety of the structure nor to provide a guarantee on its future integrity. Rather the purpose of the program is to identify potentially hazardous conditions to the extent they can be identified by a visual examination. The assessment of the general condition of the dam is based upon available data (if any) and visual inspections. Detailed investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify the need for more detailed studies. In view of the limited nature of the Phase I studies no assurance can be given that all deficiencies have been identified.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with any data which may be available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action removes the normal load on the structure, as well as the reservoir head along with seepage pressures, and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through frequent inspections can unsafe conditions be detected, so that corrective action can be taken. Likewise continued care and maintenance are necessary to minimize the possibility of development of unsafe conditions.

PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam	Richwoods Mine "B" Mill Dam
State Located	Missouri
County Located	Washington
Stream	Unnamed Tributary of Ditch Creek
Date of Inspection	3 June 1980

Richwoods Mine "B" Mill Dam, Missouri Inventory Number 31404 was inspected by Richard Berggreen (engineering geologist), David Hendron (geotechnical engineer), and Sean Tseng (hydrologist). The dam is an active barite tailings dam.

The dam inspection was made following the guidelines presented in the "Recommended Guidelines for Safety Inspections of Dams". These guidelines were developed by the Chief of Engineers, US Army, Washington, D.C., with the help of federal and state agencies, professional engineering organizations, and private engineers. The resulting guidelines represent a consensus of the engineering profession. They are intended to provide an expeditious identification, based on available data and a visual inspection of those dams which may pose hazards to human life or property. In view of the limited nature of the studies, no assurance can be given that all deficiencies have been identified.

The St Louis District, Corps of Engineers, has classified this dam as a high hazard dam; we concur with this classification. The estimated damage zone extends approximately twelve mi downstream. Within this damage zone are a barite processing plant, a tailings dam (Missouri No. 30469) and approximately 5 occupied dwellings.

Richwoods Mine "B" Mill Dam is in the intermediate size classification based on its maximum height of 48 ft. Its storage capacity is 196 ac-ft.

Our inspection and evaluation indicate the dam is in an unsatisfactory condition. Potential for severe erosion where the discharge channel flows along the toe of the dam, and excessively steep downstream slopes, 34 to 35°, suggest the long-term stability of the dam is questionable. The lack of a designed spillway is a deficiency. However, the low area at the southwest end of the embankment acts as an informal spillway.

The hydrologic analysis shows that the dam will be overtopped for any substantial precipitation event. However, overtopping will be confined to the low area at the

southwest end of the embankment and will not occur along the main dam embankment for a 1 percent probability-of-occurrence event (100-year flood) or for the Probable Maximum Flood (PMF). The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

It is recommended the following remedial measures and additional studies be undertaken, under the guidance of an engineer experienced in the design and construction of dams, for the facilities at Richwoods Mine "B" Mill Dam:

1. Discharge from the impoundment should be channeled away from the toe of the dam to prevent further erosion and oversteepening of the downstream embankment slope.

2. Design and construction of a spillway with adequate capacity.

3. Structural and seismic stability and seepage analyses should be made to meet the standards of the dam safety guidelines.

4. A warning system should be developed for advising plant employees should hazardous conditions develop.

5. Periodic inspections should be undertaken to identify any changes in volume of seepage and turbidity of the seepage water, and to detect increased erosion caused by the discharge channel.

It is suggested the owner takes action on these recommendations without undue delay.

WOODWARD-CLYDE CONSULTANTS

Richard G. Berggreen
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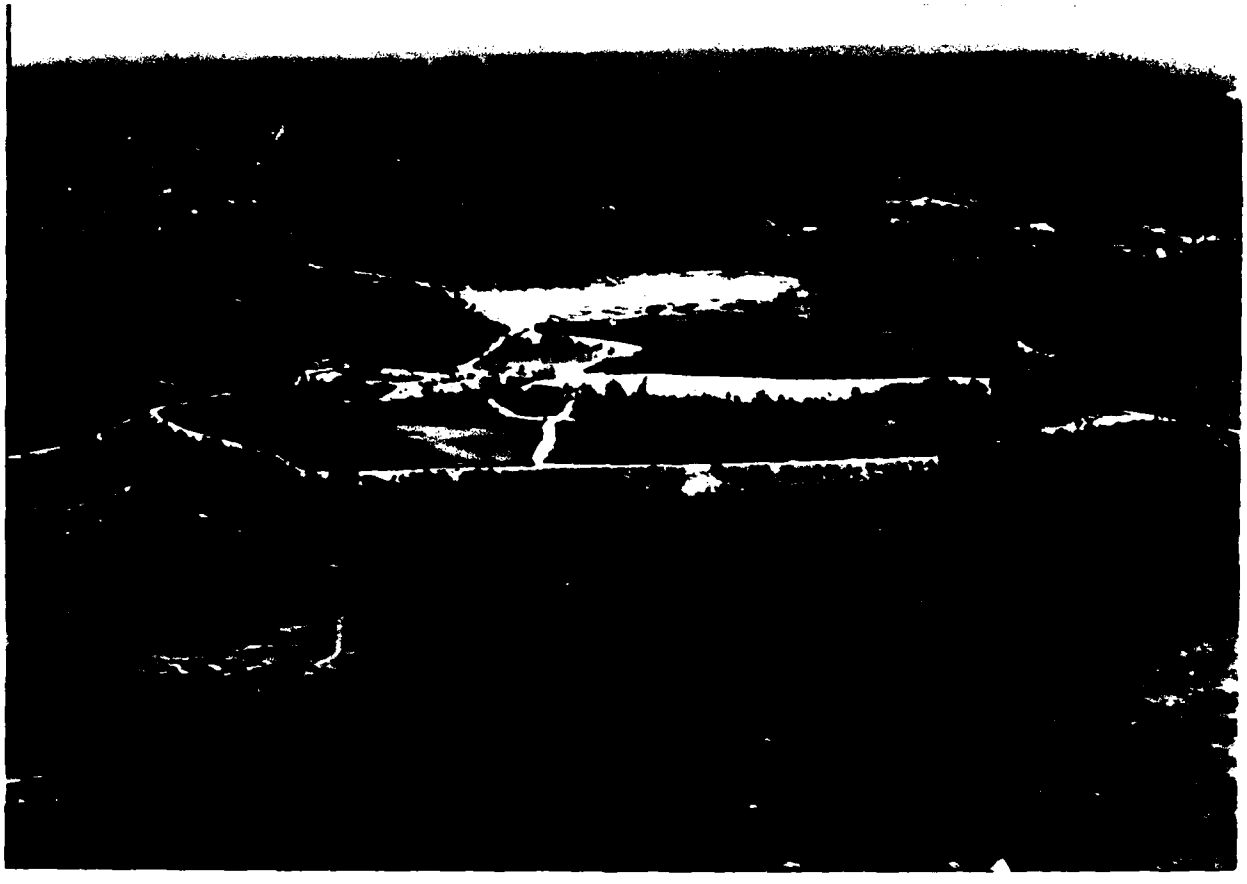

OVERVIEW
RICHWOODS MINE B MILL DAM

MISSOURI INVENTORY NUMBER MO 31404

Desoto Pit and Plant "B" Dam (MO 30469) in foreground. Richwoods Mine "B" Mill Dam (MO 31404) in background.

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
RICHWOODS MINE B MILL DAM - INVENTORY NO. 31404

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
RICHWOODS MINE B MILL DAM, MISSOURI INVENTORY NO. 31404

SECTION 1
PROJECT INFORMATION

1.1 General

a. **Authority.** The National Dam Inspection Act, Public Law 92-367, provides for a national inventory and inspection of dams throughout the United States. Pursuant to the above, an inspection was conducted of the Richwoods Mine B Mill Dam, Missouri Inventory Number 31404.

b. **Purpose of inspection.** "The primary purpose of the Phase I investigation program is to identify expeditiously those dams which may pose hazards to human life or property... The Phase I investigation will develop an assessment of the general condition with respect to safety of the project based upon available data and a visual inspection to determine any need for emergency measures and conclude if additional studies, investigations and analyses are necessary and warranted". "Chapter 3, Recommended Guidelines for Safety Inspection of Dams).

c. **Evaluation criteria.** The criteria used to evaluate the dam were established in the "Recommended Guidelines for Safety Inspection of Dams", "Engineering Regulation No. 1110-2-106 and Engineering Circular No. 1110-2-188", Engineering and Design National Program for Inspection of Non-Federal Dams, prepared by the Office of Chief of Engineers, Department of the Army, and "Hydrologic/Hydraulic Standards Phase I Safety Inspection of Non-Federal Dams" prepared by the St Louis District, Corps of Engineers. These guidelines were developed with the help of several federal agencies and many state agencies, professional engineering organizations and private engineers.

1.2 Description of Project

a. **Description of dam and appurtenances.** Richwoods Mine B Mill Dam is an active tailings dam. Its construction procedure and its usage are typical of other such dams in the area. A brief description of the general construction procedure and usage of Missouri barite tailings dams is necessary to appreciate the unique nature of these dams and understand the differences between these dams and more conventional water-retaining dams.

At the start of a barite mining operation in this area, a 10 to 20-ft high starter dam is typically first constructed across a natural stream channel. Generally the streams are intermittent so that construction is carried out in the dry. Trees and other vegetation are removed from the dam site and then a cutoff is often made to shallow bedrock. Locally obtained earth, usually a gravelly clay, is then placed to form the embankment. Compaction is limited to that provided by the construction equipment.

The barite ore is found at shallow depth within the residual gravelly clay which is mined with earth-moving equipment. At the processing plant, the ore is washed to loosen and remove the soil. This water is obtained from the reservoir area behind the dam. The soil-laden, wash water and water from other steps in the process is then discharged into the reservoir. There, the soil is deposited by sedimentation and the water recycled. Another step in the process removes the gravel-sized waste which is called "chat".

As the level of the fine tailings impounded in the reservoir increases, the dam is raised. The usual method is to dump chat on the dam crest. The chat is spread over the crest so that a relatively constant crest width is maintained as the dam is raised. Generally the crest centerline location is also maintained. However, the crest centerline location will move upstream if there is insufficient chat available or downstream if an excessive quantity of chat is available. The latter is uncommon because it is indicative of a poor ore deposit.

This method of construction results in embankment slopes which are close to the natural angle of repose for the chat. They can be considered to be near a state of incipient failure.

A large quantity of water is required for barite processing, on the order of 2000 to 5000 gal/min. Thus, it has been the operators' practice to construct the dam so that all inflow to the reservoir is recycled in order to have sufficient water for the operation. The result is that formal spillways or regulating outlets are generally not constructed. In some cases a low point on or near the dam is provided for overflow should the reservoir storage capacity be exceeded.

The fine tailings typically fill more than 80 percent of the total storage volume. This results from the operator's practice of maintaining only a 2 to 5 ft elevation differential between the level of the tailings and the dam crest.

The geotechnical characteristics of the fine tailings are somewhat similar to recent lacustrine clay deposits. Where the tailings have been continuously submerged, they have a very soft consistency and high water content. When evaporation causes the water level to recede and the tailings are exposed, a stiff crust forms as the tailings dry out. Below the crust, the tailings retain their soft consistency for long periods of time.

Richwoods Mine B Mill Dam is approximately 3700 ft long and borders the impoundment area on the north, east and south. It is approximately 48 ft high at the maximum section. There is no designed spillway for this dam. A low area at the southwest end of the embankment acts as an informal spillway. An 8 in. diameter pipe crosses beneath the road along the south side of the reservoir and is the only outlet structure identified. The pipe has corroded to the point of being inoperative. Some overflow from the reservoir flows across the road at approximately the same location as the pipe. The lowest point controlling overflow is elevation 872 ft MSL on the road (see Photo 7). Elevations on the dam crest vary from 884 ft to 872 ft MSL.

b. **Location.** The dam is located 1.6 mi NE of Richwoods, Washington County, Missouri. It is on an unnamed tributary of Ditch Creek in Survey #2161, Washington County Barite District on the USGS Richwoods NE 7.5 minute quadrangle map.

c. **Size classification.** The dam is classified intermediate due to its 48 ft height. Its storage capacity is 196 ac-ft. This storage volume does not include the fine tailings impounded by the dam.

d. **Hazard classification.** The St Louis District, Corps of Engineers has classified this dam high hazard; we concur with this classification. The estimated damage zone extends approximately 12 mi downstream of the dam. Within this damage zone are 5 dwellings, a barite processing mill, and another tailings dam (MO 30469). The barite plant and tailings dam are immediately below this reservoir. The potential loss of life and property is high in the event of a dam failure.

e. **Ownership.** We understand the dam is owned by Desoto Minerals Co, Box 35, Richwoods, Missouri 63071. Correspondence should be addressed to Mr Durward Spees.

f. **Purpose of dam.** The dam was constructed to impound fine barite tailings produced by washing of barite ore mined in the vicinity. The impoundment serves as a settling basin. Water is recycled from the pond and re-used in the barite processing operation.

g. **Design and construction history.** The owner has no record of the design and construction of the dam. The owner's representative, Mr Spees, stated during the inspection that the level of tailings behind the dam increases by 1 to 2 ft per year. The dam itself is raised in lifts, 4 to 5 ft thick, as necessary to maintain 2 to 3 ft of elevation difference between the level of the tailings and the dam crest.

h. **Normal operating procedures.** Water from the processing plant is discharged into the impoundment as shown in Fig. A1, Appendix A. Discharge from the pond passes over the uncontrolled, informal spillway at the west abutment and flows east (in some places along the downstream toe of the dam) to a second settling pond. No records of the water levels or flows are kept.

1.3 Pertinent Data

a. **Drainage area.** approximately 0.15 mi^2

b. **Discharge at dam site.**

Maximum known flood at damsite	Unknown
Warm water outlet at pool elevation	N/A
Diversion tunnel low pool outlet at pool elevation	N/A
Diversion tunnel outlet at pool elevation	N/A
Gated spillway capacity at pool elevation	N/A
Gated spillway capacity at maximum pool elevation	N/A
Ungated spillway capacity at maximum pool elevation	No formal spillway
Total spillway capacity of maximum pool elevation	No formal spillway

c. **Elevations (ft above MSL).**

Top of Dam	872 to 884
Maximum pool - design surcharge	N/A
Full flood control pool	N/A
Recreation pool	N/A
Spillway crest (gated)	N/A
Upstream portal invert diversion tunnel	N/A
Downstream portal invert diversion tunnel	N/A
Streambed at centerline of dam	Unknown
Maximum tailwater	N/A
Toe of dam at maximum section	836

d. **Reservoir.**

Length of maximum pool	approximately 2900 ft
Length of recreation pool	N/A
Length of flood control pool	N/A

e. **Storage (acre-feet).**

Recreation pool	N/A
Flood control pool	N/A
Design surcharge	N/A

Top of dam	196 (This volume does not include the volume occupied by the fine tailings impounded by the dam.)

f. **Reservoir surface (acres).**

Top of dam	49
Maximum pool	49
Flood control pool	N/A
Recreation pool	N/A
Spillway crest	N/A

g. **Dam.**

Type	Barite tailings
Length	approximately 3,700 ft
Height	approximately 48 ft
Top width	15 to 25 ft
Side slopes	Downstream 1.5(H) to 1(V); Upstream Unknown
Zoning	Unknown (probably none)
Impervious core	Unknown (probably none)
Cutoff	Unknown (probably shallow trench to bedrock)
Grout curtain	Unknown (probably none)

h. **Diversion and regulating tunnel.**

Type	None
Length	N/A
Closure	N/A
Access	N/A
Regulating facilities	None

i. **Spillway.**

Type	No formal spillway has been constructed for this dam. For any substantial precipitation event, a low area at the southwest end of the embankment acts as an informal spillway.
Length of weir	approximately 250 ft
Crest elevation	872 ft
Gates	None
Downstream channel	Flow runs alongside parts of the toe of the dam and beneath the plant located immediately downstream of the toe of the dam.

j. **Regulating outlets.** None

SECTION 2
ENGINEERING DATA

2.1 Design

No design drawings or other design data are known to exist.

2.2 Construction

No construction records are known to exist. Construction is apparently typical of barite dams in the area. See section 1.2.a. The dam is active and construction is continuing by the addition of chat to the dam crest.

2.3 Operation

No operation records are known to exist.

2.4 Evaluation

a. **Availability.** No engineering data were found for this facility.

b. **Adequacy.** Insufficient data were available to determine the adequacy of the design. Seepage and stability analyses comparable to the requirements of the guidelines are not on record. This is a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record. These analyses should be performed by an engineer experienced in the design and construction of dams.

c. **Validity.** Not applicable.

2.5 Project Geology

The dam site lies on the northern flank of the Ozark structural dome. The regional dip is to the north. The bedrock in the area is mapped as Cambrian age Eminence and Potosi dolomite formations on the Geologic Map of Missouri (Fig. 4). The Potosi Formation is a medium-to fine-grained, light gray dolomite, and typically contains an abundance of quartz druse characteristic of chert bearing formations. The Eminence Formation comformably overlies the Potosi Formation, and is similar in appearance but contains less quartz and chert. Some caves and large springs have been found in the Eminence in parts of Missouri; however, at the site, no evidence of solution activity was noted during the field inspection.

The soil at the dam site is a dark red-brown, plastic residual clay (CH), characteristically developed on the Potosi Formation. It is locally overlain by 1 to 5 ft of silty loess (ML). The area is mapped on the Missouri General Soils Map as Union-Goss-Gasconade-Peridge Association.

The Richwoods Fault zone lies approximately 1.5 mi south of the dam site and is mapped on the Structural Features Map of Missouri (1971) as discontinuous for approximately 19 mi, in a WNW-ESE direction. The Ditch Creek Fault System is located about 3-1/2 miles north of the site and is mapped on the Structural Features map as approximately 11 miles long, paralleling the Richwoods Fault zone. The Ditch Creek System is mapped as north side down; the Richwoods fault is mapped as north side up. These faults are Pre-Cambrian in age and are not in a seismically active area. They are not considered to pose a significant hazard to the dam.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. **General.** Dam was inspected on 3 June 1980 without the owner's representative present. This inspection indicated the dam is in an unsatisfactory condition.

b. **Dam.** The Richwoods Mine B Mill Dam consists of coarse tailings locally referred to as "chat". This material is sandy gravel and sand (GW, SW). It is cohesionless and can be easily eroded. The material is end-dumped on the crest of the dam by trucks. Compaction is limited to truck traffic. Slopes on the dam generally are at the angle of repose for this material, 33 to 35 degrees. A 40 degree slope angle was measured on portions of the maximum section (Fig. 3B).

The embankment is essentially free of vegetation and no signs of substantial failures were observed. There was no evidence of sinkhole development, detrimental settlement, depressions, cracking or animal burrows.

The discharge channel passes along the toe of a portion of the dam (Fig. A1, Appendix A; Photos 3 and 4). In this area, it appears the channel has eroded the toe of the slope. Evidence of small (less than 5 yd^3) slope failures was noted in this area (Photo 3).

Several ponds are located along the toe of this dam. These ponds inhibit identification of seepage along much of the toe of this dam. Minor seepage at the toe of the maximum section was estimated at 1 to 2 gal/min. The seepage water did not appear to be carrying fine soil particles.

c. **Appurtenant structures.** No designed spillway was identified at this dam. There is, however, a low area near the southwest end of the embankment which serves as an informal spillway (Fig. A1, Appendix A). The elevation difference between this area and the remainder of the embankment is maintained so that overflow occurs there during normal plant operations.

d. **Reservoir area.** Approximately 60 percent of the fine tailings surface was above water level at the time of inspection. The reservoir area is underlain by fine tailings which consist of an impervious mixture of sand, silt and clay. There is a dense growth of willow-type vegetation over much of the exposed portion of the impoundment area.

In the flooded area, maximum water depth was estimated at about 8 ft at the time of inspection.

Slopes surrounding the reservoir area are quite flat and estimated to be less than 10(H): 1(V). No indication of potential instability was observed at the time of the inspection.

e. **Downstream channel.** The downstream channel runs through an irregular, mined-out area parallel to the toe of the south portion of the dam embankment. The channel flows through ponds (see Fig. A-1, Appendix A). For most of its length, the gradient on the downstream channel is flat enough that erosion should not result from high velocity flows. However, where it flows immediately along the toe of the dam, the channel is confined by the adjacent roadway and significant erosion of the embankment could occur during substantial flows.

3.2 Evaluation

Our evaluation indicates the dam is in an unsatisfactory condition. There was no evidence of sinkhole development, detrimental settlement, animal burrows, depressions or cracking at the time of our visual inspection. However, erosion at the toe of the dam caused by discharge channel flows and the excessively steep slopes are considered deficiencies. The lack of a designed spillway is also considered a

deficiency. It is recommended an engineering analysis be conducted to evaluate the long-term stability of this dam due to its continued use and increasing height of the embankment.

Seepage through the embankment did not appear to constitute a hazard, at the time of the inspection, due to its low volume and lack of soil in the observed seepage flow. However, possible seepage into the ponds along the toe of the embankment could not be identified.

SECTION 4
OPERATIONAL PROCEDURES

4.1 Procedures

There are no operational procedures for this dam.

4.2 Maintenance of Dam

The dam is continually being raised to maintain 2 to 3 ft of elevation differential between the dam embankment crest and the fine tailings level. The low area at the southwest abutment which is the overflow point is also raised and compacted, mainly by truck traffic, as the tailings level increases.

4.3 Maintenance of Operating Facilities

No maintenance is apparently performed on the operating facilities. The outlet pipe buried under the overflow section of the embankment has deteriorated through corrosion to the point of being inoperative.

4.4 Description of Any Warning System in Effect

Our inspection did not disclose any warning system is in effect at this dam.

4.5 Evaluation

There is no plan for periodic inspection of the dam or appurtenant facilities. Maintenance is limited to raising the embankment level as the tailings level rises. The lack of inspections and maintenance as considered a deficiency. The lack of a warning system is also considered a deficiency.

SECTION 5
HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

a. **Design data.** No hydrologic or hydraulic design information was available for evaluation of the dam or the reservoir; however, February 1980 topographic maps with a scale of 1:2400 (1 in. equals 200 ft) were supplied by Desoto Mining Company. Other dimensions of the dam and reservoir were measured and/or surveyed on the date of inspection or estimated from topographic maps. The map used in the analysis was the advance print of the USGS Richwoods NE 7.5-minute quadrangle map.

b. **Experience data.** No recorded rainfall, runoff, discharge, or pool stage data were available for this reservoir and dam.

c. **Visual observations.** The visual inspection disclosed there is no designed spillway at this dam. The discharge channel flows parallel to the toe of the embankment through an irregular mined-out area which could become congested during a flood. Other observations regarding the reservoir, spillway and downstream channel are presented in Section 3, Visual Inspection.

Seepage through the embankment noted during the visual inspection is not hydrologically significant in the overtopping analysis.

d. **Overtopping potential.** The overtopping hydrologic analysis for this dam was performed using the "HEC-1, Dam Safety Version" (1 April 1980) computer program. The method used, the data and output summaries are presented in Appendix B. For the hydrologic/hydraulic analyses, the low area at the southwest end of the embankment was considered part of the dam. The elevation of this area is maintained so that overflow occurs during normal plant operations. Therefore, the analyses show that the dam is overtopped by any precipitation event. However, overtopping is confined to this low area

(approximately 250 ft in length) and does not occur along the main embankment even for the 1 percent probability-of-occurrence or Probable Maximum Flood (PMF) events. The roadway in this overflow area appears moderately compacted by traffic and should have only a low potential for erosion. The PMF is defined as the flood event which may be expected to occur from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

The following results were obtained for the dam from the hydrologic/hydraulic analyses presented in Appendix B:

Precipitation Event	Max Reservoir W.S. Elev. ft (MSL)	Max Depth of Overtopping ft	Max Outflow ft^3/sec	Duration of Overtopping hrs
25% PMF	872.7	0.7	26	48*
50% PMF	873.2	1.2	102	48*
100% PMF	874.0	2.0	331	48*

*Since the starting water surface elevation is at the low area crest elevation, the duration of overtopping will always be approximately equal to the storm duration.

SECTION 6
STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. **Visual observations.** Visual observations which adversely affect the structural stability of this dam are reported in Section 3. Conditions of specific note include erosion at the toe of the dam along the discharge channel, and the extremely steep face of the downstream slope of the embankment.

b. **Design and construction data.** No design or construction data relating to the structural stability of the dam were found. In particular, seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency.

c. **Operating records.** No appurtenant structures requiring operation exist at this dam. A 8-in. diameter steel pile buried under the roadway at the southwest end of the dam is inoperative.

d. **Post construction changes.** Construction of the dam is continuing. The height of the embankment is increased at the rate of 1 to 2 ft each year. The final intended height of the embankment is not known.

e. **Seismic stability.** The dam is in Seismic Zone 2, to which the guidelines assign a moderate damage potential. Since no static stability analysis is available for review, the seismic stability cannot be evaluated. However, as the tailings are fine-grained, saturated materials and the dam is made of loose, granular material, substantial deformation damage or failure could occur in the event of a severe seismic event.

SECTION 7
ASSESSMENT/REMEDIAL MEASURES

7.1 Dam Assessment

a. **Safety.** Based on the visual inspection, Richwoods Mine B Mill Dam appears to be in unsatisfactory condition. This judgment is based primarily on the potential for erosion of the downstream toe adjacent to the discharge channel, the lack of a designed spillway, and the steep slopes of the downstream face of the embankment.

As a consequence of the widely-used procedure for construction of barite tailings dams, the slopes of the dams are placed at the angle of natural repose for the material. This results in slopes which are very steep and exist near incipient failure with safety factors approximately equal to one. Gradual improvement of the factor of safety against overall slope failure can be expected with time, as consolidation and desiccation of the impounded fine-grained tailings increase their strength and decrease the driving forces acting on the embankment.

The slopes placed at the angle of natural repose will only remain stable if they are protected against changes that will increase load or decrease strength. Such changes include but may not be limited to the following:

1. Overtopping by water.

2. Higher pore pressures (or seepage forces).

3. Undercutting of the toe of the slope by erosion or mining activity.

4. Increase in the height of the slope (applicable to active operations).

5. Liquefaction (such as may result from a seismic event).

The first four changes are subject to control by owners and operators and must receive careful attention to maintain stable dam embankments. The fifth influence represents a risk, the magnitude of which cannot be estimated without further study.

b. **Adequacy of information.** Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available; this precludes an evaluation of the structural and seismic stability of the dam. The lack of these analyses is considered a deficiency.

c. **Urgency.** The deficiencies described in this report could affect the safety of the dam. Corrective actions should be initiated without undue delay.

d. **Necessity for Phase II.** In accordance with the Recommended Guidelines for Safety Inspections of Dams, the subject investigation was a minimum study. This study revealed that additional in-depth investigations are needed to complete the assessment of the safety of the dam. Those investigations which should be performed without undue delay are described in Section 7.2.b. It is our understanding from discussions with the St Louis District that any additional investigations are the responsibility of the owner.

7.2 Remedial Measures

a. **Alternatives.** There are several general options available which may be considered to reduce the possibility of dam failure or to diminish the harmful consequences of such a failure. Some of these options are:

1. Remove the dam, or breach it to prevent storage of water.

2. Increase the height of dam and/or spillway size to pass the probable maximum flood without overtopping the dam.

3. Purchase downstream land that would be adversely impacted by dam failure and restrict human occupancy.

4. Enhance the stability of the dam to permit overtopping by the probable maximum flood without failure.

5. Provide a highly reliable flood warning system (generally does not prevent damage but decrease chances of loss of life).

b. **Recommendations.** Based on our inspection of Richwoods Mine B Mill Dam, it is recommended that further study be conducted without undue delay, under the guidance of an engineer experienced in the design and construction of dams, to evaluate, as a minimum:

1. Rechanneling of the downstream discharge channel away from the toe of the dam to prevent further erosion and oversteepening of the embankment downstream slope.

2. Design and construction of a spillway of adequate capacity. Consideration should also be given to erosion protection in the spillway area.

3. The establishment of an effective, practical warning system for plant employees should be investigated.

c. **Operation and maintenance procedures.** A program of periodic inspections should be initiated to identify evidence of slope instability such as cracking or slumping, increases in the amount of seepage flow or turbidity of the seepage water, and evidence of erosion in the informal spillway and/or discharge channel. Reports of inspections and any recommended maintenance should be made a matter of record.

REFERENCES

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St Louis District, US Army Corps of Engineers, 1979, "Hydrologic/Hydraulic Standards, Phase I Safety Inspection of Non-Federal Dams".

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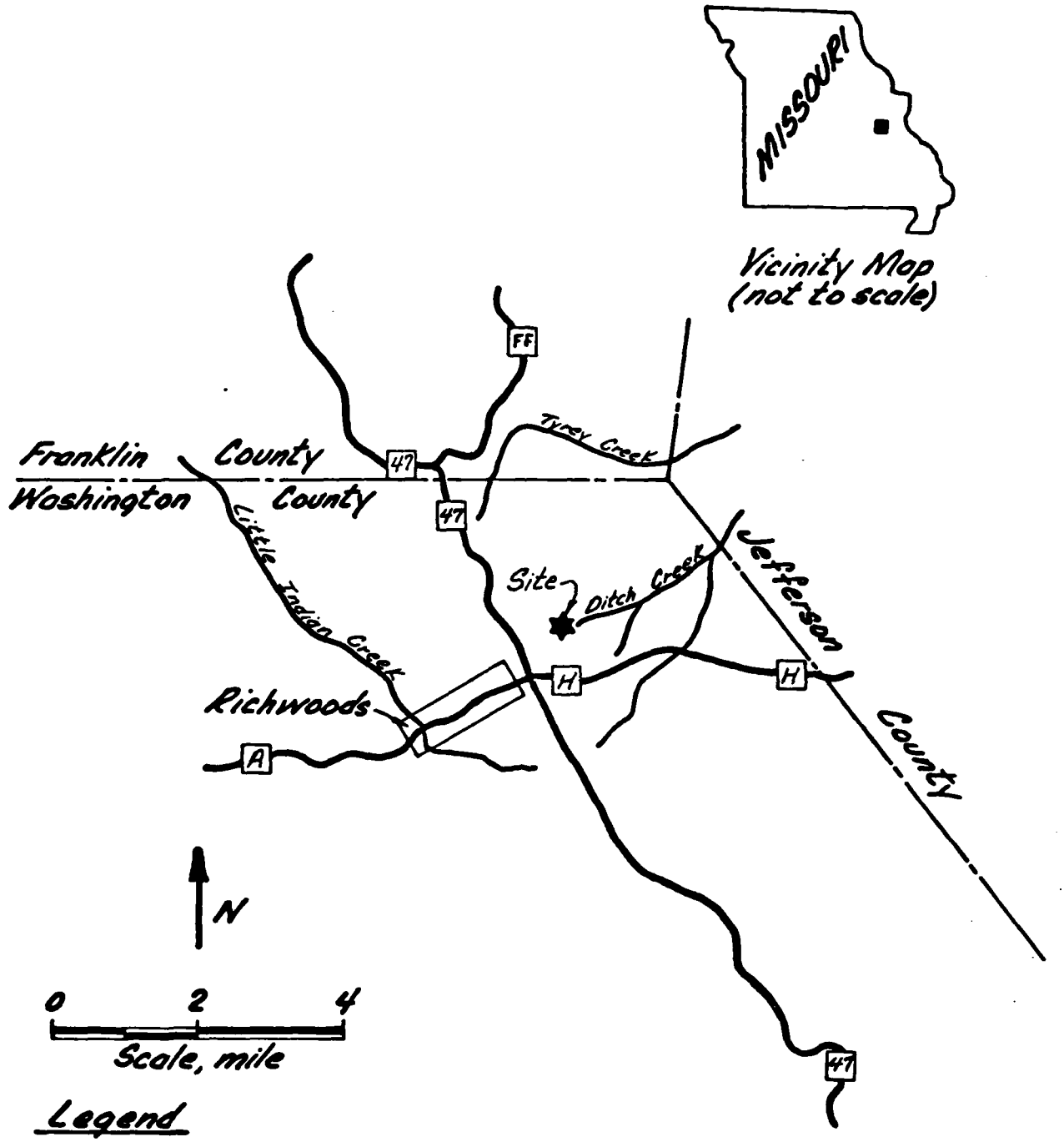
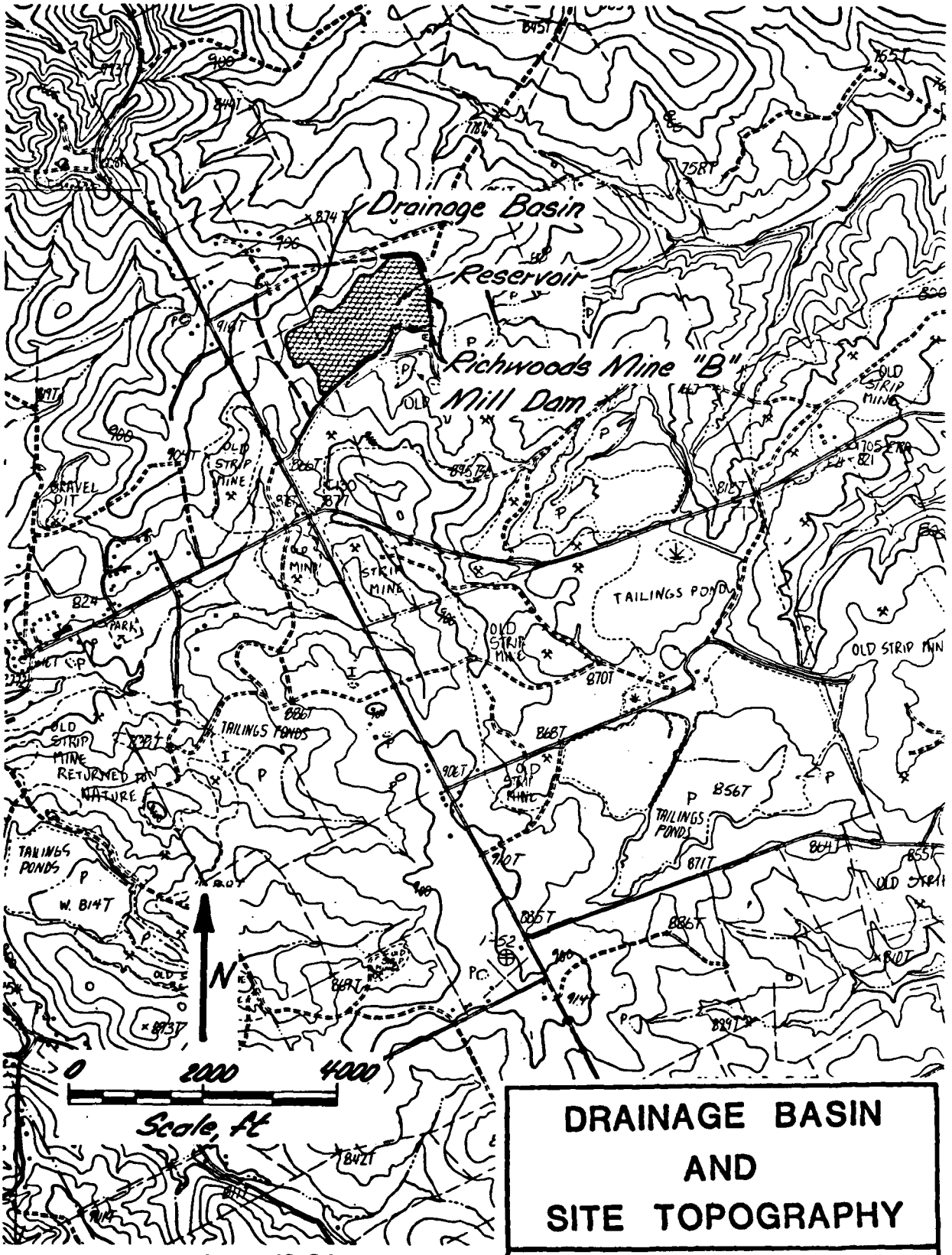
US Soil Conservation Service, 1971, "National Engineering Handbook," Section 4, Hydrology, 1971.



Legend

- County line
- A — State highway and Route No.
- Creek — River or creek
- Tiff — City or town
- Project location

SITE LOCATION MAP	
RICHWOODS MINE 'B' MILL DAM	
MO. 31404	Fig. 1

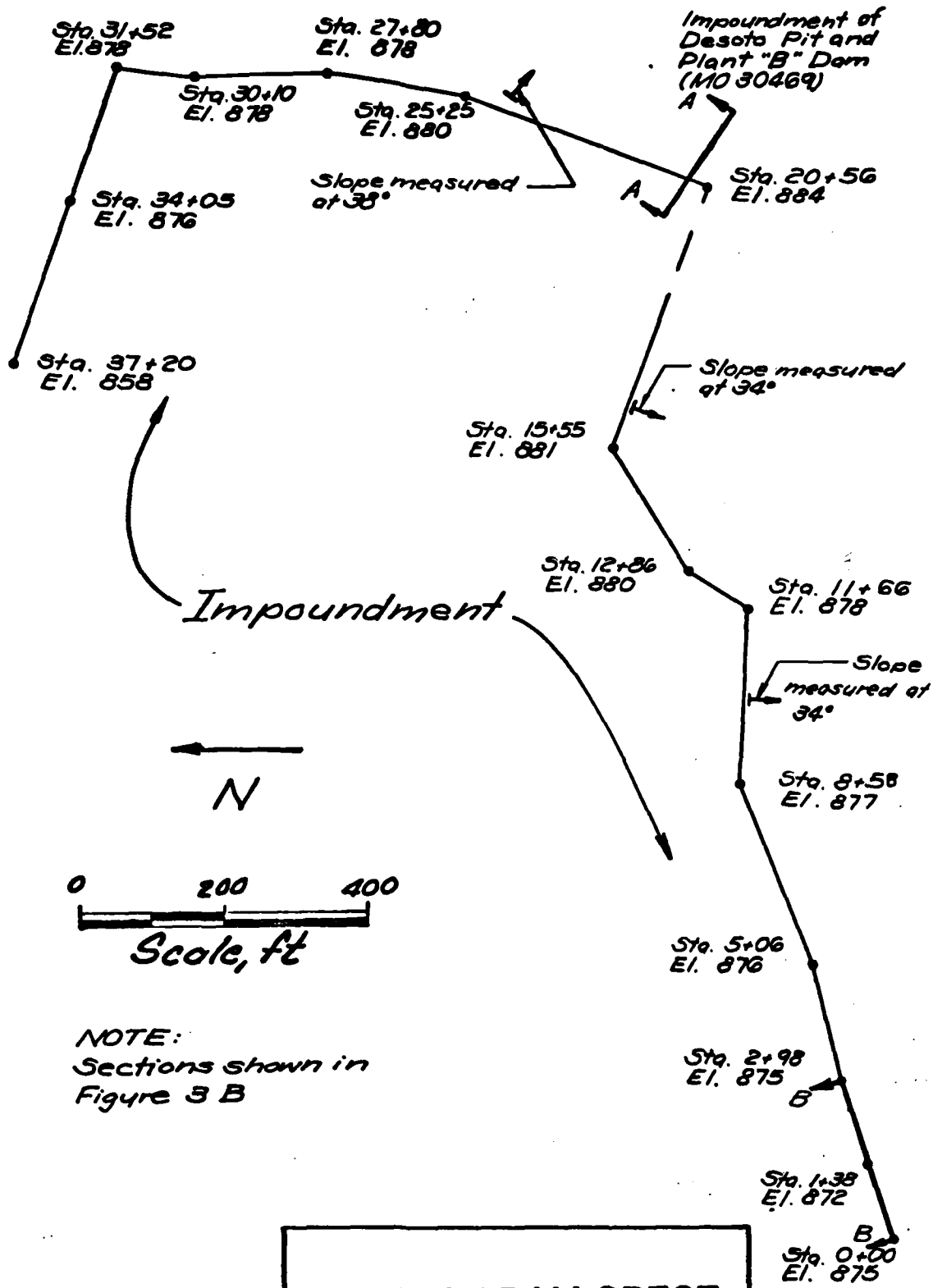


1. Topography from U.S.G.S. Richwoods N.E. 7½ minute quadrangle map.

DRAINAGE BASIN AND SITE TOPOGRAPHY

RICHWOODS MINE 'B' MILL DAM

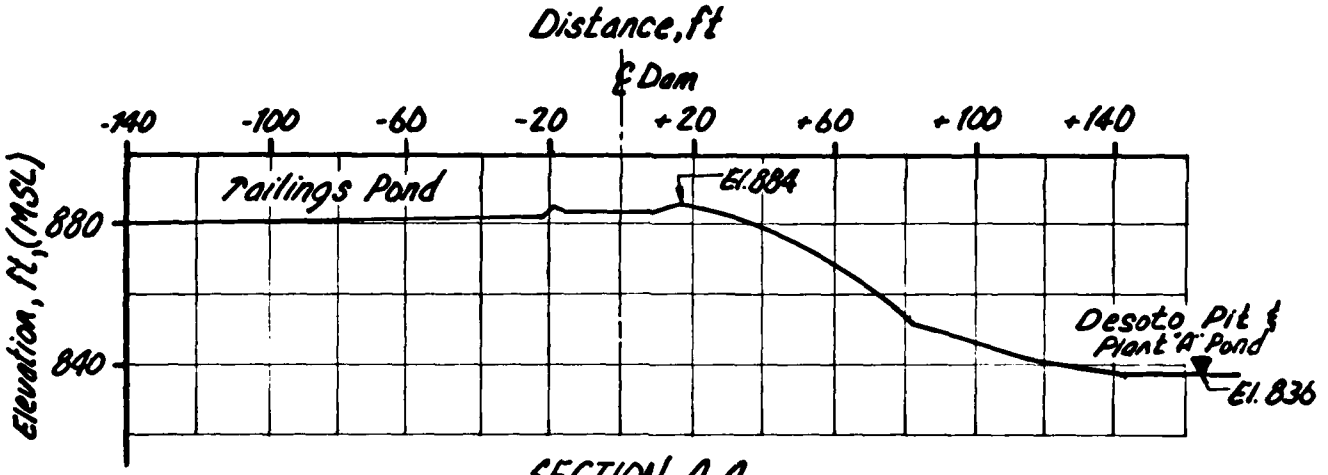
MO. 31404	Fig. 2



PLAN OF DAM CREST

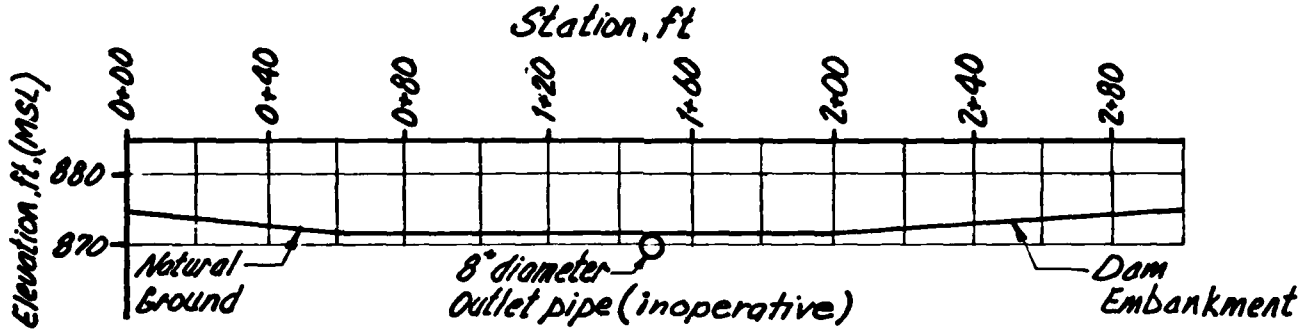
RICHWOODS MINE 'B' MILL DAM

MO. 31404 | Fig. 3 A



SECTION A-A

Maximum Cross-Section



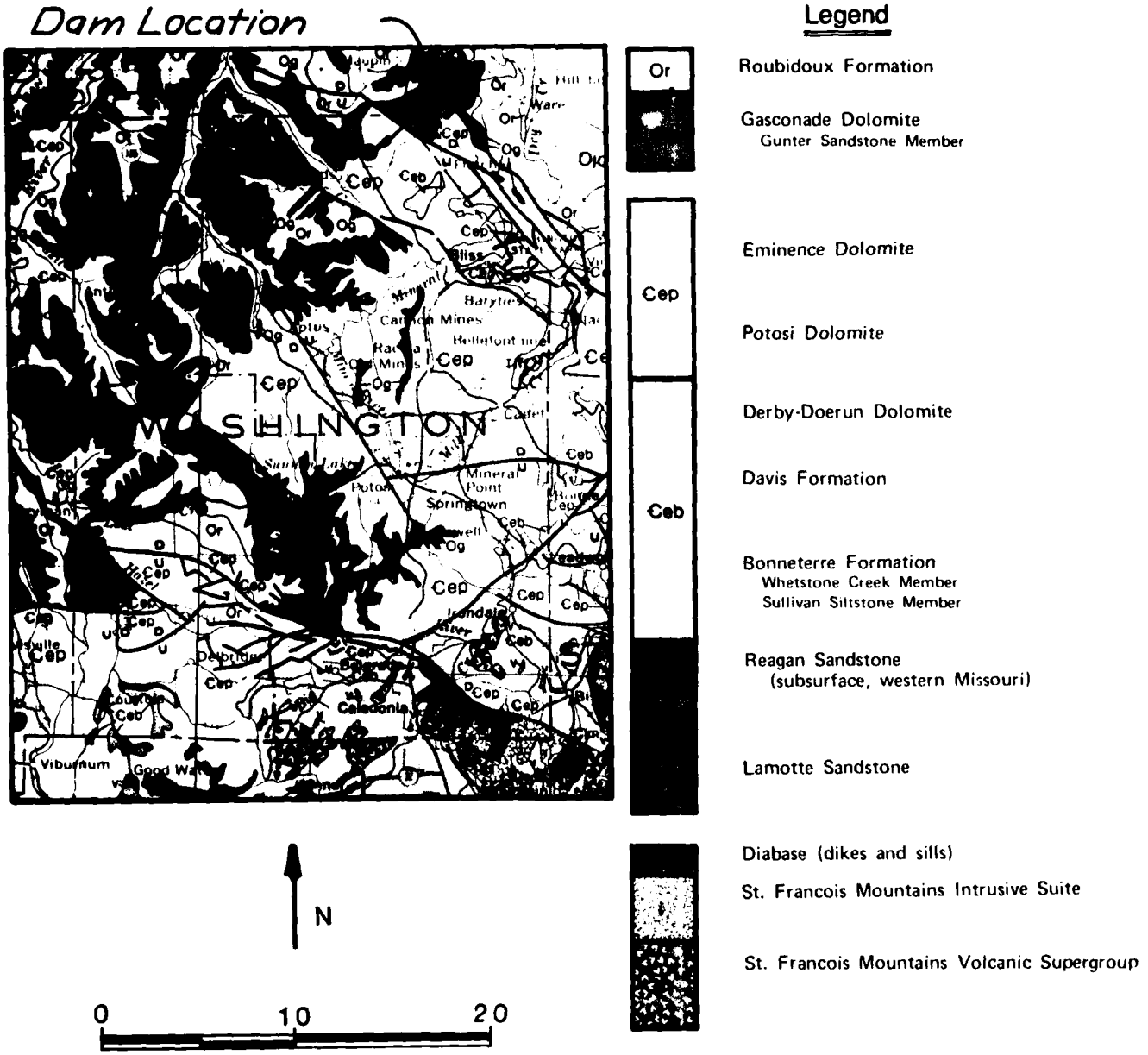
SECTION B-B

Informal Spillway Profile

Note:

Topography from 1in.= 200 ft maps supplied by Desoto Mining Co.

CROSS-SECTIONS OF DAM & SPILLWAY	
RICHWOODS MINE 'B' MILL DAM	
MO. 31404	Fig. 3B



Legend

- Or — Roubidoux Formation
- Gasconade Dolomite
  - Gunter Sandstone Member
- Cep — Eminence Dolomite
- Potosi Dolomite
- Ceb — Derby-Doerun Dolomite
- Davis Formation
- Bonneterre Formation
  - Whetstone Creek Member
  - Sullivan Siltstone Member
- Reagan Sandstone (subsurface, western Missouri)
- Lamotte Sandstone
- Diabase (dikes and sills)
- St. Francois Mountains Intrusive Suite
- St. Francois Mountains Volcanic Supergroup

REGIONAL GEOLOGIC MAP

RICHWOODS MINE 'B' MILL DAM

MO. 31404	Fig. 4

APPENDIX A

Photographs

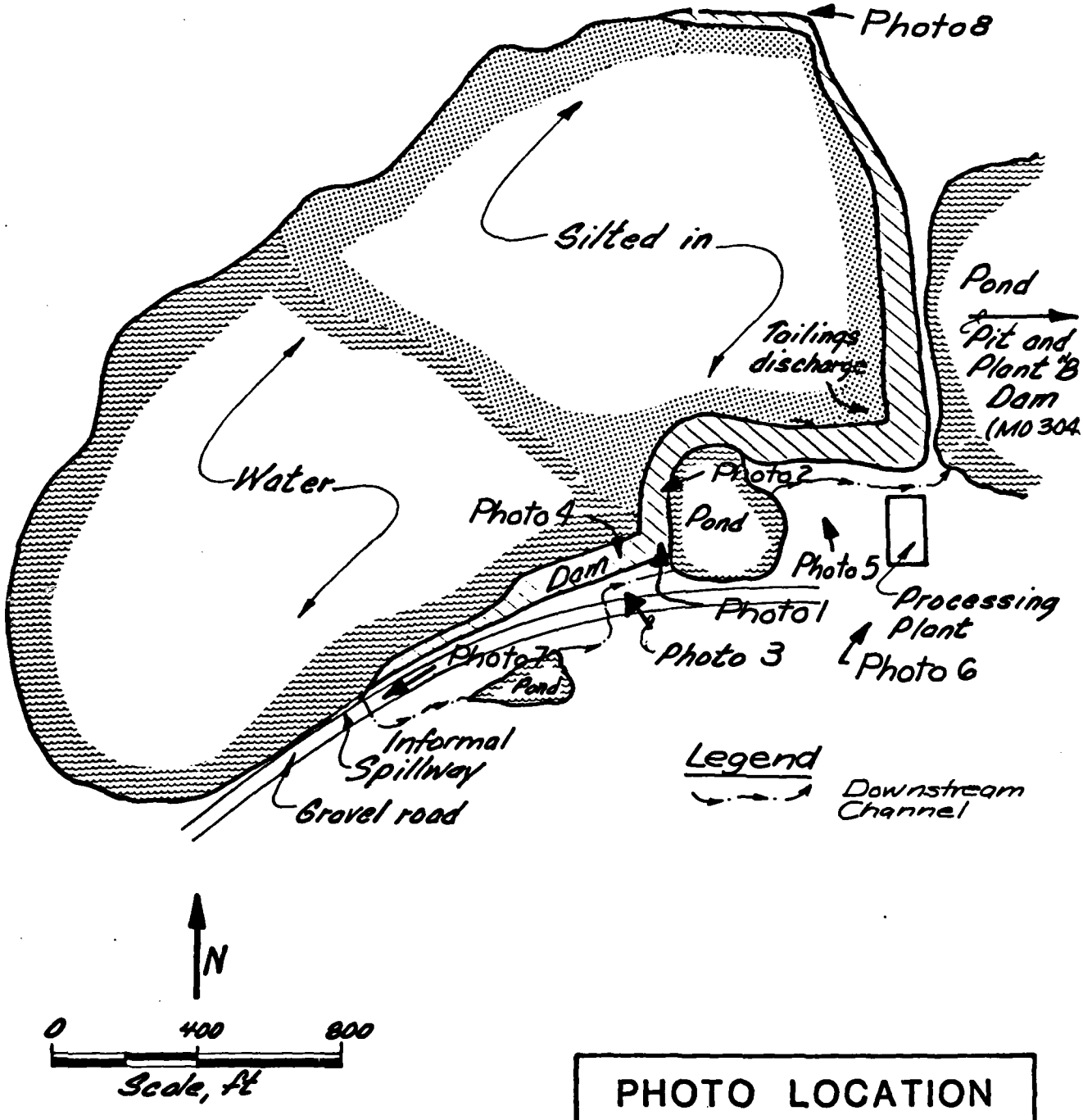
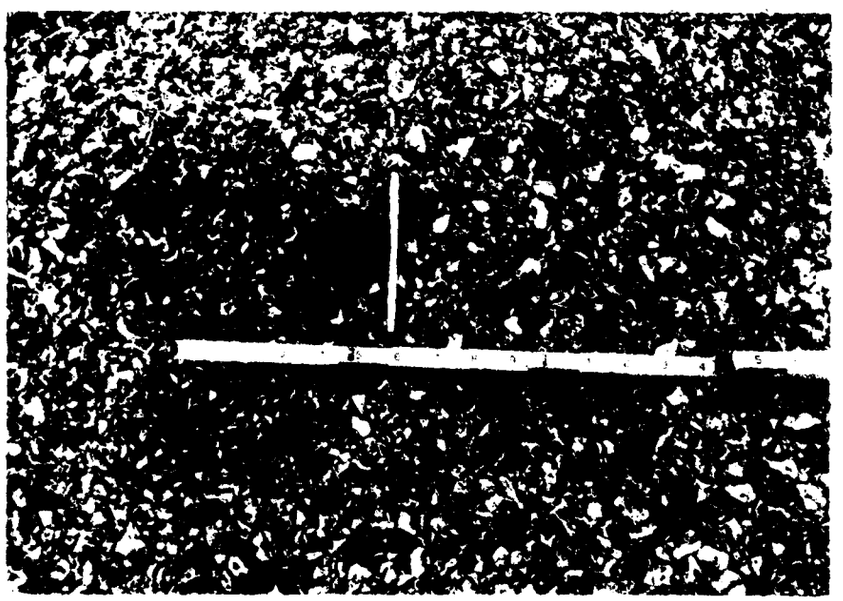


PHOTO LOCATION SKETCH	
RICHWOODS MINE 'B' MILL DAM	
MO. 31404	Fig. A-1

1. End dumped tailings used to construct dam. Looking north along crest.



2. Close-up of "chat" on surface of dam.

3. Slumping on face of embankment due to erosion by discharge channel.

4. Gravel bar in discharge channel from erosion at toe of dam.

5. Main dam embankment in background. Settling pond with seepage in foreground.

6. Barite processing plant immediately below dam.

7. Overflow crossing road. Reservoir to right. Looking west. Discharge pipe in background to right.

8. Dike along north side of impoundment, showing 1½ to 2 feet freeboard.

APPENDIX B

Hydraulic/Hydrologic Data and Analyses

APPENDIX B

Hydraulic/Hydrologic Data and Analyses

B.1 Procedures

a. **General.** The hydraulic/hydrologic analyses were performed using the "HEC-I, Dam Safety Version (1 Apr 80)" computer program. Based on the input drainage basin parameters, the program develops a synthetic unit hydrograph from which the reservoir inflow hydrograph is derived. The inflow is then routed by the "modified-Puls" method through the reservoir to determine the outflow hydrograph and assess the overtopping potential.

b. **Precipitation events.** The duration of the probable maximum storms and the 1 and 10 percent probability-of-occurrence storms was 48 hours. For the probable maximum storms, the probable maximum precipitation was determined from regional charts prepared by the US Weather Bureau (1956). The 1 and 10 percent probability-of-occurrence rainfall distributions were provided by the St Louis District, Corps of Engineers.

c. **Unit hydrograph.** The Soil Conservation Service (SCS) unit hydrograph for a storm duration of 48 hrs was used to develop the inflow hydrograph. The unit hydrograph was divided into 10 min intervals.

d. **Infiltration losses.** The SCS curve number (CN) loss function was used to account for infiltration losses. Curve numbers were selected on the basis of antecedent moisture conditions in accordance with the guidelines, present land usage and hydrologic soil groups within the drainage basin.

e. **Lag time.** Lag time was computed by the SCS method (National Engineering Handbook, Section 4, Equation 15-4).

B.2 Pertinent Data

a. **Drainage area:** 0.15 mi^2

b. **Lag time:** 0.27 hrs

c. **Hydrologic soil group:** C

d. **SCS curve numbers.**

1. For PMF: 92 (AMC III)
2. For 1 and 10 percent probability-of-occurrence events: 82 (AMCII)

e. **Storage.** Elevation-area data were developed by planimetering areas at various elevation intervals on the USGS advance print Richwoods NE Missouri (1960) 7.5-minute quadrangle map. The data were entered on the $A and $E cards to enable the HEC-I program to compute storage volumes.

f. **Outflow capacity.** The spillway rating curve was computed by the intrinsic formula within the HEC-I program. Pertinent spillway data required by the program were entered on the $$ card.

g. **Outflow over crest.** As the profile of the dam is irregular, flow over the crest were computed according to the "Flow Over Non-Level Dam Crest" supplement to the HEC-I User's Manual. The crest data and constraints were entered on the $D, SL and $V cards.

h. **Reservoir elevations.** For the probabilistic floods and 50 and 100 percent PMF floods, the overflow point elevation of 872 ft was used as starting elevation.

B.3 Results

Results of the analyses as well as the input values to the HEC-I program pertaining to various fractions of the Probable Maximum Flood (PMF) follow this index. Only results summaries are included, not intermediate calculation step results. Complete copies of the HEC-I input and output are available in the project file.

```
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION  JULY 1978
 LAST MODIFICATION  01 APR 80
```

```
    1          A1    DAM MO 31404 RICHWOODS MINE B. MILL
    2          A2    WOODWARD-CLYDE CONSULTANTS, HOUSTON JOB NO. 79CH004
    3          A3    PROBABLE MAXIMUM FLOW(PMF) ANALYSIS
    4          B   288       0      10      -0      -0      -0      -0      -0      -0      -0
    5          B1    9
    6          J     1       4       1
    7          J1  .25     .50     .75     1.0
    8          K     0  INFLOW                                    1
    9          K1      INFLOW HYDROGRAPH CALCULATION
   10          M     1       2   0.15
   11          P    0.     20.    102.    120.    130.    140.
   12          T                                                 -1     -92            0.70
   13          W2          0.27
   14          K    -1    -.09       3
   15          K     1     DAM                                    1
   16          K1      OUTFLOW HYDROGRAPH, ROUTING AND OVERTOPPING ANALYSIS
   17          V                                  1
   18          Y1    1                                       -872.
   19          SA    0.     54.     68.     76.     84.
   20          SE  825.    860.    872.    880.    890.
   21          SS  872.     0      2.9     1.5
   22          SD  872.    2.6     1.5
   23          SL    0     320     600    1230    2210    2960
   24          SV  872     878     880     882     884     886
   25          K    99
```

Input Summary
Various PMF Events
Richwoods Mine "B" Mill Dam
MO 31404
B3

```
FLOOD HYDRO    M PACKAGE (HEC-1)
DAM SAFETY V. SION     JULY 1978
 LAST MODIFICATION  01 APR 80
**********************************
 RUN  DATE= 29 JUL 80
      TIME= 12.35.00

                    DAM NO 31404 RICHWOODS MINE B. MILL
                     HOOVARD-CLYDE CONSULTANTS, HOUSTON JOB NO. 79CH004
                     PROBABLE MAXIMUM FLOW(PMF) ANALYSIS

                                    JOB SPECIFICATION
          NO      NHR     NMIN     IDAY      IHR     IMIN    METRC     IPLT     IPRT    NSTAN
         288       0       10       -0       -0       -0       -0       -0       -0       -0
                                   JOPER      NWT    LROPT    TRACE
                                       5       -0       -0       -0

                              MULTI-PLAN ANALYSES TO BE PERFORMED
                                  NPLAN= 1 NRTIO= 4 LRTIO= 1
                         RTIOS=     .25      .50      .75     1.00

**********          **********          **********          **********          **********

                                  SUB-AREA RUNOFF COMPUTATION

                    INFLOW HYDROGRAPH CALCULATION

                              ISTAO   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
                             INFLOW       0      -0      -0      -0       1      -0      -0      -0

                                        HYDROGRAPH DATA
                   IHYDG    IUNG   TAREA    SNAP   TRSDA   TRSPC   RATIO   ISNOW   ISAME   LOCAL
                       1       2     .19      -0.     .19     -0.     -0.      -0      -0      -0

                                          PRECIP DATA
                              SPFE     PMS      R6     R12     R24     R48     R72     R96
                              0.     24.00   102.00  120.00  130.00  140.00    -0.     -0.
          TRSPC COMPUTED BY THE PROGRAM IS  .800

                                          LOSS DATA
          LROPT   STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
             -0     -0.     -0.    1.00     -0.     -0.    1.00   -1.00  -92.00     -0.     .70

          CURVE NO =  -92.00  WETNESS =   -1.00  EFFECT CN =   92.00

                                      UNIT HYDROGRAPH DATA
                                   TC= -0.      LAG=  .27

                                      RECESSION DATA
                                STRTQ=   -1.00    QRCSN=    -.05    RTIOR= 5.00

                    TIME INCREMENT TOO LARGE--IHHQ IS GT LAG/2)

                    UNIT HYDROGRAPH 10 END OF PERIOD ORDINATES, TC=   -0.   HOURS, LAG=   .27  VOL= 1.00
                  89.     205.     159.      70.      33.      15.       7.       3.       2.       1.
```

Input Summary
Various PMF Events
Richwoods Mine "B" Mill Dam
MO 31404
B4

END-OF-PERIOD FLOW

MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q	MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.01	.10	1	.00	.00	.00	0.	1.02	.10	145	.02	.02	.00	3.
1.01	.20	2	.00	.00	.00	0.	1.02	.20	146	.02	.02	.00	7.
1.01	.30	3	.00	.00	.00	1.	1.02	.30	147	.02	.02	.00	10.
1.01	.40	4	.00	.00	.00	1.	1.02	.40	148	.02	.02	.00	12.
1.01	.50	5	.00	.00	.00	1.	1.02	.50	149	.02	.02	.00	12.
1.01	1.00	6	.00	.00	.00	1.	1.02	1.00	150	.02	.02	.00	13.
1.01	1.10	7	.00	.00	.00	1.	1.02	1.10	151	.02	.02	.00	13.
1.01	1.20	8	.00	.00	.00	1.	1.02	1.20	152	.02	.02	.00	13.
1.01	1.30	9	.00	.00	.00	1.	1.02	1.30	153	.02	.02	.00	13.
1.01	1.40	10	.00	.00	.00	1.	1.02	1.40	154	.02	.02	.00	13.
1.01	1.50	11	.00	.00	.00	1.	1.02	1.50	155	.02	.02	.00	13.
1.01	2.00	12	.00	.00	.00	1.	1.02	2.00	156	.02	.02	.00	13.
1.01	2.10	13	.00	.00	.00	1.	1.02	2.10	157	.02	.02	.00	13.
1.01	2.20	14	.00	.00	.00	1.	1.02	2.20	158	.02	.02	.00	13.
1.01	2.30	15	.00	.00	.00	1.	1.02	2.30	159	.02	.02	.00	13.
1.01	2.40	16	.00	.00	.00	1.	1.02	2.40	160	.02	.02	.00	13.
1.01	2.50	17	.00	.00	.00	1.	1.02	2.50	161	.02	.02	.00	13.
1.01	3.00	18	.00	.00	.00	1.	1.02	3.00	162	.02	.02	.00	13.
1.01	3.10	19	.00	.00	.00	1.	1.02	3.10	163	.02	.02	.00	13.
1.01	3.20	20	.00	.00	.00	1.	1.02	3.20	164	.02	.02	.00	13.
1.01	3.30	21	.00	.00	.00	1.	1.02	3.30	165	.02	.02	.00	13.
1.01	3.40	22	.00	.00	.00	1.	1.02	3.40	166	.02	.02	.00	13.
1.01	3.50	23	.00	.00	.00	1.	1.02	3.50	167	.02	.02	.00	13.
1.01	4.00	24	.00	.00	.00	1.	1.02	4.00	168	.02	.02	.00	13.
1.01	4.10	25	.00	.00	.00	1.	1.02	4.10	169	.02	.02	.00	13.
1.01	4.20	26	.00	.00	.00	1.	1.02	4.20	170	.02	.02	.00	13.
1.01	4.30	27	.00	.00	.00	1.	1.02	4.30	171	.02	.02	.00	13.
1.01	4.40	28	.00	.00	.00	1.	1.02	4.40	172	.02	.02	.00	13.
1.01	4.50	29	.00	.00	.00	1.	1.02	4.50	173	.02	.02	.00	13.
1.01	5.00	30	.00	.00	.00	1.	1.02	5.00	174	.02	.02	.00	13.
1.01	5.10	31	.00	.00	.00	1.	1.02	5.10	175	.02	.02	.00	13.
1.01	5.20	32	.00	.00	.00	1.	1.02	5.20	176	.02	.02	.00	13.
1.01	5.30	33	.00	.00	.00	1.	1.02	5.30	177	.02	.02	.00	13.
1.01	5.40	34	.00	.00	.00	1.	1.02	5.40	178	.02	.02	.00	13.
1.01	5.50	35	.00	.00	.00	1.	1.02	5.50	179	.02	.02	.00	13.
1.01	6.00	36	.00	.00	.00	1.	1.02	6.00	180	.02	.02	.00	13.
1.01	6.10	37	.01	.01	.00	1.	1.02	6.10	181	.10	.10	.00	20.
1.01	6.20	38	.01	.01	.00	2.	1.02	6.20	182	.10	.10	.00	36.
1.01	6.30	39	.01	.01	.00	3.	1.02	6.30	183	.10	.10	.00	49.
1.01	6.40	40	.01	.01	.00	3.	1.02	6.40	184	.10	.10	.00	55.
1.01	6.50	41	.01	.01	.00	3.	1.02	6.50	185	.10	.10	.00	57.
1.01	7.00	42	.01	.01	.00	3.	1.02	7.00	186	.10	.10	.00	58.
1.01	7.10	43	.01	.01	.00	3.	1.02	7.10	187	.10	.10	.00	59.
1.01	7.20	44	.01	.01	.00	3.	1.02	7.20	188	.10	.10	.00	59.
1.01	7.30	45	.01	.01	.00	3.	1.02	7.30	189	.10	.10	.00	60.
1.01	7.40	46	.01	.01	.00	3.	1.02	7.40	190	.10	.10	.00	60.
1.01	7.50	47	.01	.01	.00	3.	1.02	7.50	191	.10	.10	.00	60.
1.01	8.00	48	.01	.01	.00	3.	1.02	8.00	192	.10	.10	.00	60.
1.01	8.10	49	.01	.01	.00	3.	1.02	8.10	193	.10	.10	.00	60.
1.01	8.20	50	.01	.01	.00	3.	1.02	8.20	194	.10	.10	.00	60.
1.01	8.30	51	.01	.01	.00	3.	1.02	8.30	195	.10	.10	.00	60.
1.01	8.40	52	.01	.01	.00	3.	1.02	8.40	196	.10	.10	.00	60.
1.01	8.50	53	.01	.01	.00	3.	1.02	8.50	197	.10	.10	.00	60.
1.01	9.00	54	.01	.01	.00	3.	1.02	9.00	198	.10	.10	.00	60.
1.01	9.10	55	.01	.01	.00	3.	1.02	9.10	199	.10	.10	.00	60.
1.01	9.20	56	.01	.01	.00	3.	1.02	9.20	200	.10	.10	.00	60.
1.01	9.30	57	.01	.01	.00	3.	1.02	9.30	201	.10	.10	.00	60.
1.01	9.40	58	.01	.01	.00	3.	1.02	9.40	202	.10	.10	.00	60.
1.01	9.50	59	.01	.01	.00	3.	1.02	9.50	203	.10	.10	.00	60.
1.01	10.00	60	.01	.01	.00	3.							

Input Summary
Various PMF Events
Richwoods Mine "B" Mill Dam
MO 31404

1.01	10.10	61	.01	.01	.00	3.	1.02	10.10	205	.10	.10	.00	60.
1.01	10.20	62	.01	.01	.00	3.	1.02	10.20	206	.10	.10	.00	60.
1.01	10.30	63	.01	.01	.00	3.	1.02	10.30	207	.10	.10	.00	60.
1.01	10.40	64	.01	.01	.00	4.	1.02	10.40	208	.10	.10	.00	60.
1.01	10.50	65	.01	.01	.00	4.	1.02	10.50	209	.10	.10	.00	60.
1.01	11.00	66	.01	.01	.00	4.	1.02	11.00	210	.10	.10	.00	60.
1.01	11.10	67	.01	.01	.00	4.	1.02	11.10	211	.10	.10	.00	60.
1.01	11.20	68	.01	.01	.00	4.	1.02	11.20	212	.10	.10	.00	60.
1.01	11.30	69	.01	.01	.00	4.	1.02	11.30	213	.10	.10	.00	60.
1.01	11.40	70	.01	.01	.00	4.	1.02	11.40	214	.10	.10	.00	60.
1.01	11.50	71	.01	.01	.00	4.	1.02	11.50	215	.10	.10	.00	60.
1.01	12.00	72	.01	.01	.00	4.	1.02	12.00	216	.10	.10	.00	60.
1.01	12.10	73	.03	.02	.01	9.	1.02	12.10	217	.35	.35	.00	92.
1.01	12.20	74	.03	.02	.01	8.	1.02	12.20	218	.35	.35	.00	133.
1.01	12.30	75	.03	.02	.00	11.	1.02	12.30	219	.35	.35	.00	172.
1.01	12.40	76	.03	.02	.00	12.	1.02	12.40	220	.35	.35	.00	189.
1.01	12.50	77	.03	.02	.00	13.	1.02	12.50	221	.35	.35	.00	198.
1.01	13.00	78	.03	.02	.00	13.	1.02	13.00	222	.35	.35	.00	207.
1.01	13.10	79	.03	.03	.00	14.	1.02	13.10	223	.42	.42	.00	209.
1.01	13.20	80	.03	.03	.00	15.	1.02	13.20	224	.42	.42	.00	225.
1.01	13.30	81	.03	.03	.00	16.	1.02	13.30	225	.42	.42	.00	236.
1.01	13.40	82	.03	.03	.00	16.	1.02	13.40	226	.42	.42	.00	242.
1.01	13.50	83	.03	.03	.00	16.	1.02	13.50	227	.42	.42	.00	244.
1.01	14.00	84	.03	.03	.00	16.	1.02	14.00	228	.42	.42	.00	245.
1.01	14.10	85	.04	.04	.00	17.	1.02	14.10	229	.53	.53	.00	259.
1.01	14.20	86	.04	.04	.00	19.	1.02	14.20	230	.53	.53	.00	277.
1.01	14.30	87	.04	.04	.00	20.	1.02	14.30	231	.53	.53	.00	294.
1.01	14.40	88	.04	.04	.00	21.	1.02	14.40	232	.53	.53	.00	301.
1.01	14.50	89	.04	.04	.00	21.	1.02	14.50	233	.53	.53	.00	305.
1.01	15.00	90	.04	.04	.00	21.	1.02	15.00	234	.53	.53	.00	306.
1.01	15.10	91	.04	.03	.00	21.	1.02	15.10	235	.48	.48	.00	303.
1.01	15.20	92	.06	.06	.00	23.	1.02	15.20	236	.81	.81	.00	322.
1.01	15.30	93	.11	.10	.01	31.	1.02	15.30	237	1.45	1.45	.00	437.
1.01	15.40	94	.20	.20	.02	50.	1.02	15.40	238	3.03	3.03	.00	807.
1.01	15.50	95	.08	.08	.00	83.	1.02	15.50	239	1.05	1.05	.00	1150.
1.01	16.00	96	.05	.05	.00	71.	1.02	16.00	240	.64	.64	.00	984.
1.01	16.10	97	.04	.04	.00	48.	1.02	16.10	241	.50	.49	.00	699.
1.01	16.20	98	.04	.04	.00	34.	1.02	16.20	242	.50	.49	.00	469.
1.01	16.30	99	.04	.04	.00	27.	1.02	16.30	243	.50	.49	.00	371.
1.01	16.40	100	.04	.04	.00	24.	1.02	16.40	244	.50	.49	.00	328.
1.01	16.50	101	.04	.04	.00	23.	1.02	16.50	245	.50	.49	.00	309.
1.01	17.00	102	.04	.04	.00	22.	1.02	17.00	246	.50	.49	.00	296.
1.01	17.10	103	.03	.03	.00	21.	1.02	17.10	247	.39	.39	.00	281.
1.01	17.20	104	.03	.03	.00	19.	1.02	17.20	248	.39	.39	.00	257.
1.01	17.30	105	.03	.03	.00	18.	1.02	17.30	249	.39	.39	.00	240.
1.01	17.40	106	.03	.03	.00	17.	1.02	17.40	250	.39	.39	.00	232.
1.01	17.50	107	.03	.03	.00	17.	1.02	17.50	251	.39	.39	.00	229.
1.01	18.00	108	.03	.03	.00	17.	1.02	18.00	252	.39	.39	.00	227.
1.01	18.10	109	.00	.00	.00	12.	1.02	18.10	253	.03	.03	.00	145.
1.01	18.20	110	.00	.00	.00	9.	1.02	18.20	254	.03	.03	.00	122.
1.01	18.30	111	.00	.00	.00	5.	1.02	18.30	255	.03	.03	.00	66.
1.01	18.40	112	.00	.00	.00	4.	1.02	18.40	256	.03	.03	.00	52.
1.01	18.50	113	.00	.00	.00	3.	1.02	18.50	257	.03	.03	.00	44.

Input Summary
Various PMF Events
Richwoods Mine "B" Mill Dam
MO 31404

1.01	18.50	113	.00	.00	.00	3.	1.02	18.50	257	.03	.03	.00	44.
1.01	19.00	114	.00	.00	.00	3.	1.02	19.00	258	.03	.03	.00	38.
1.01	19.10	115	.00	.00	.00	2.	1.02	19.10	259	.03	.03	.00	32.
1.01	19.20	116	.00	.00	.00	2.	1.02	19.20	260	.03	.03	.00	27.
1.01	19.30	117	.00	.00	.00	2.	1.02	19.30	261	.03	.03	.00	23.
1.01	19.40	118	.00	.00	.00	1.	1.02	19.40	262	.03	.03	.00	20.
1.01	19.50	119	.00	.00	.00	1.	1.02	19.50	263	.03	.03	.00	20.
1.01	20.00	120	.00	.00	.00	2.	1.02	20.00	264	.03	.03	.00	20.
1.01	20.10	121	.00	.00	.00	2.	1.02	20.10	265	.03	.03	.00	20.
1.01	20.20	122	.00	.00	.00	2.	1.02	20.20	266	.03	.03	.00	20.
1.01	20.30	123	.00	.00	.00	2.	1.02	20.30	267	.03	.03	.00	20.
1.01	20.40	124	.00	.00	.00	2.	1.02	20.40	268	.03	.03	.00	20.
1.01	20.50	125	.00	.00	.00	2.	1.02	20.50	269	.03	.03	.00	20.
1.01	21.00	126	.00	.00	.00	2.	1.02	21.00	270	.03	.03	.00	20.
1.01	21.10	127	.00	.00	.00	2.	1.02	21.10	271	.03	.03	.00	20.
1.01	21.20	128	.00	.00	.00	2.	1.02	21.20	272	.03	.03	.00	20.
1.01	21.30	129	.00	.00	.00	2.	1.02	21.30	273	.03	.03	.00	20.
1.01	21.40	130	.00	.00	.00	2.	1.02	21.40	274	.03	.03	.00	20.
1.01	21.50	131	.00	.00	.00	2.	1.02	21.50	275	.03	.03	.00	20.
1.01	22.00	132	.00	.00	.00	2.	1.02	22.00	276	.03	.03	.00	20.
1.01	22.10	133	.00	.00	.00	2.	1.02	22.10	277	.03	.03	.00	20.
1.01	22.20	134	.00	.00	.00	2.	1.02	22.20	278	.03	.03	.00	20.
1.01	22.30	135	.00	.00	.00	2.	1.02	22.30	279	.03	.03	.00	20.
1.01	22.40	136	.00	.00	.00	2.	1.02	22.40	280	.03	.03	.00	20.
1.01	22.50	137	.00	.00	.00	2.	1.02	22.50	281	.03	.03	.00	20.
1.01	23.00	138	.00	.00	.00	2.	1.02	23.00	282	.03	.03	.00	20.
1.01	23.10	139	.00	.00	.00	2.	1.02	23.10	283	.03	.03	.00	20.
1.01	23.20	140	.00	.00	.00	2.	1.02	23.20	284	.03	.03	.00	20.
1.01	23.30	141	.00	.00	.00	2.	1.02	23.30	285	.03	.03	.00	20.
1.01	23.40	142	.00	.00	.00	2.	1.02	23.40	286	.03	.03	.00	20.
1.01	23.50	143	.00	.00	.00	2.	1.02	23.50	287	.03	.03	.00	20.
1.02	0.	144	.00	.00	.00	2.	1.03	0.	288	.03	.03	.00	20.
									SUM	29.12	28.81	.31	16787.
										740.11	732.11	8.11	474.681

Input Summary
Various PMF Events
Richwoods Mine "B" Mill Dam
MO 31404

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIOS APPLIED TO FLOWS RATIO 1 .25	RATIO 2 .50	RATIO 3 .75	RATIO 4 1.00
HYDROGRAPH AT	INFLOW	.15	1	288.	575.	863.	1150.
		(.391	(	8.141(	16.291(	24.431(	32.571(
ROUTED TO	DAM	.15	1	26.	102.	204.	331.
		(.391	(	.751(	2.891(	5.791(	9.391(

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SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1		INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
	ELEVATION	872.00	872.00	872.00
	STORAGE	1360.	1360.	1360.
	OUTFLOW	0.	0.	0.

Approximate Max. Velocity on dam

	RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
4 fps	.25	872.71	.71	1409.	26.	48.00	42.33	0.
5 fps	.50	873.23	1.23	1444.	102.	48.00	42.17	0.
6 fps	.75	873.62	1.62	1472.	204.	48.00	41.17	0.
6.5 fps	1.00	873.96	1.96	1496.	331.	48.00	40.67	0.

Output Summary
Various PMF Events
Richwoods Mine "B" Mill Dam
MO 31404


ATE
LME